On Biomembranes

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Biological membranes are an integral part of all living cells. Although these membranes are different in each organism, and many different membranes with various functions often exist in the same cell, they share similar compositions and properties. The general purpose of biological membranes is compartmentation. They form the boundary around sub-cellular components and surround the cell itself, sequestering it from the immediate environment. Biological membranes are so vital to life as we know it, that it is hard to envision a viable cell without a cell membrane. How did the membrane come to be a universal component and a sine qua non in the biological machinery of life?

To speak of "the biological membrane" is to indulge in generalities. While all membranes are composed mainly of lipid and protein molecules, are a few molecules in thickness, and are closed, each membrane is an individual. The membranes surrounding the cell are unique to each organism. Moreover, each cell usually contains membranes which close off sub-cellular structures known as "organelles", whose composition and properties may be grossly different from the membrane which surrounds the cell itself. As well, the farther we progress ~~down~~ along the road of microscopic evolution, we find an increase

in the complexity and specialization of function in the cell membrane itself as well as sub-cellular membranes. It thus appears that membrane development is concurrent with evolutionary development.

The most urgent function of biomembranes is compartmentation. When the membrane enclosing the cell is injured, the cell contents simply spill out. But the membrane is much more than just a bag; otherwise polyethylene would do just as well. Membranes also control and regulate the molecular species which pass through them, in both directions. Cell membranes bring in substrates which the cell metabolizes for energy and growth. It is also responsible for maintaining the required concentrations of inorganic ions in the intracellular solution. Thus the membrane wages a continuous battle against such physical laws as osmosis, electric potential, and entropy.

Many membranes also engage in more specific and specialized activities. The membranes of the mitochondria and the chloroplast are responsible for energy conversion, myelin acts as an electrical insulator in nerve cells, and a good deal of protein synthesis in 'higher' organisms is carried out on the surface of the endoplasmic reticulum.

If we accept the hypothesis that complicated biological systems are the evolutionary product of simpler ones, then we can also assume that the variety of biological membranes

that exist today originated with one or a few more basic membrane precursors. In this case, biological membranes are the result of divergent microevolution. Early in the history of life a membrane existed around the cell. This membrane was modified as living cells themselves developed.

The opposite can also be postulated: Membranes are similar because of convergence, and not divergence. Early in the evolutionary process, cells had different manners of compartmentation. Some used fatty acids instead of lipids, perhaps. Some may have used polyethylene, for all we know. But as evolution continued, the membranes of all living systems evolved to the better ~~xyxtemsx~~ composition and properties. That is why the systems which have evolved to date bear general similarities.

Although there are examples of convergence in macro-evolution, in which two different species developed similar characteristics in adapting to a common environment, such convergence on a molecular or microscopic level is more difficult to accept. A good counter-example is the genetic code. The nucleus and chromosomes of mammals are far more complicated than the genetic apparatus of bacteria, but the molecular basis for each is the same. The genetic message is carried on molecules of DNA in the same code, regardless of the organism, regardless of the encompassing ~~genx~~ genetic apparatus. One can argue that during evolution living cells attempted a variety of molecules to carry genetic information, and in the course of time, found that

DNA was undoubtedly the best molecule for the job, and went over to it. So far the argument is acceptable. But if the choice of DNA occurred in different places in different eras, how does one explain that the code itself is universal? The base sequence dictates the same polypeptide sequence in every known organism. GGU says glycine to an elephant and an amoeba. It is not plausible that such an arbitrary language as the genetic code was arrived at from different directions. What does follow, however, is that all life developed from the same primitive organism that successfullyx used what has become the universal genetic code.

What morphological characteristics did this proto-organism possess? Did it also have a proto-membrane?

This question has become more popular in recent years in light of experimentation with natural, artificial, and semi-artificial membranes. It has been found, for example, that certain lipids, when shaken in water or saline solution, automatically form closed microscopic sacs, or vesicles, which, in turn possess some of the gross characteristics of cell membranes.

This could be an excellent starting point for life, provided that life began in a primeval sea. The existence of tiny vesicles, composed of fatty acids, lipids, and perhaps a few adsorbed random polypeptides created a separate phase. The liquid in the sacs eventually took on different composition than in the external sea. The next step can be visualized as the beginning of catalytic reactions, which would enrich

certain molecular species at the expense of others. These vesicles would grow and burst, forming new sacs, with the same composition and identical catalytic properties*. Only eons later did the first proto-organism begin using DNA to dictate the formation of identical macromolecules. In the interim, perhaps simpler molecular molds were used.

Now we reach an interesting point. If biological membranes ~~xaxa~~ are as old as life itself, then the biological cell must have undergone adaptation to the properties of the membrane, as well as the adaptation the membranes have undergone in response to the needs of the organism as a whole.

The adaptation of the membrane is more evident. We can trace, for example the development of the membrane bound respiration chain from relatively simple aerobic bacteria to the mitochondria. Similarly, we can see how the need for sugar substrates forced the membrane of a bacteria, Escherichia Coli to develop an efficient enzyme system within the membrane which catalyzes the transport of sugars into the cell.

Biological membranes are very permeable to water. They have no control mechanism over how much water enters the cell or leaves it. Moreover, since water comprises up to ninety percent of cellular weight, it deserves the cell's serious attention. Perhaps this great amount of water is partially superfluous, or was at one time. We can envision a proto-organism, in a saline primitive sea, surrounded by a proto-

* the catalytic properties developed also, but over long periods, and millions of generations.

membrane lacking in water regulation. The amount of water in the cell would thus be governed solely by osmotic equilibria. As time progressed, the cell accustomed itself of necessity to a large concentration of water, and some organisms developed internal pumps or thick external cell walls as ~~mechanisms~~ mechanisms to compensate the membrane's ineptitude in this respect. The high internal water concentration could at any rate be considered a necessary evil which organisms got used to in the primeval sea; so much so, in fact, that they require great amounts of water today, their whole metabolism having been thus built ~~around it~~.

Another salient example is one of salt concentration. Cells actively engage in enriching the potassium concentration and depleting the internal sodium ion concentration. Perhaps in the primeval sea there was a preponderence of potassium ions. ~~The protomembrane~~ The protomembrane did not regulate the concentrations of these ions, so they were present in the same concentration in the cell as in the sea. In time, the salt concentration in the sea changed, but the cell was forced to maintain an ionic status quo. Only then was the membrane forced to develop the potassium-sodium pump.

These points give strength to the argument that the membranes evolved from a primitive time as a function of the cell, and the cell as a function of the membrane. There is another opinion concerning biogenesis which sees the membrane in a different ~~xxfax~~ light.

Certain biological polymers in saline solution tend to aggregate into globules known as protenoid microspheres. These microspheres are capable of enzymatic activity (provided that an enzyme is one of the components), and upon addition of more polymer to the solution, these microspheres can be seen to bud, forming new globules of identical composition.

This is also a fine model for primitive biological systems. There is no immediate need for a membrane because the protenoid itself is a phase separate from the aqueous medium. Just as a chloroform-water interface has permeability characteristics so does the protenoid-water interface. Metabolism and reprod-uction are demonstrated. Who needs more?

On the other hand, the question then arises of what promoted the protocells to adopt ~~xx~~ separate phase membranes, if they were viable without them? Perhpas the initial ad-sorption of lipids to the protenoid surface was accidental?

In that case, why are membranes today universal components? And why are no organisms extant that can demonstrate viability in their absence?